

TITLE OF THE INVENTION

SEMICONDUCTOR BONDING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the  
5 benefit of priority from prior Japanese Patent  
Application No. 2003-134331, filed May 13, 2003,  
the entire contents of which are incorporated herein  
by reference.

BACKGROUND OF THE INVENTION

10 1. Field of the Invention

The present invention relates to a semiconductor  
bonding apparatus, particularly to a semiconductor  
bonding apparatus which bonds a semiconductor chip via  
an elastic member disposed between a semiconductor chip  
15 and a mounting substrate.

2. Description of the Related Art

In recent years, optical members such as a lens  
and mirror have been added to a semiconductor chip or  
a mounting substrate to be mounted on optical products  
20 such as an optical communication apparatus and  
a microscope, and an optical device has been well  
developed aiming at reduction of the number of  
components for use in the whole device, miniaturization  
of the product, and enhancement of a function. In many  
25 of these optical devices, the semiconductor chip has  
to be bonded to the mounting substrate at an interval  
which is kept as a predetermined distance in order to

effectively fulfill an optical function. There has been a demand for higher precision in the interval to be kept as compared with conventional bonding of the semiconductor chip to the mounting substrate.

5           For the conventional bonding of the semiconductor chip to the mounting substrate, there is a major demand that a mechanical bonding strength be secured and an electric conduction be obtained. There is little demand that the interval between the semiconductor  
10 chip and the mounting substrate be secured at high precision. Therefore, also for the bonding of these devices, a bonding apparatus is hardly seen including a function of controlling a height position of the semiconductor chip or the mounting substrate at a  
15 bonding time as a factor which determines the interval between the semiconductor chip and the mounting substrate with the high precision.

As the bonding apparatus which controls the height position of the semiconductor chip, there is  
20 a semiconductor manufacturing apparatus described in Jpn. Pat. Appln. KOKAI Publication No. 2002-134563. The semiconductor manufacturing apparatus of the Jpn. Pat. Appln. KOKAI Publication No. 2002-134563 will be described with reference to FIG. 8.

25           That is, a linear motor 106 which is movable in a vertical direction in accordance with control of a controller 108 is installed in the semiconductor

manufacturing apparatus. The linear motor 106 is connected to a mounted nozzle 105 which is capable of holding a semiconductor device 101. Moreover, a position sensor 107 capable of detecting the height of the mounted nozzle 105 is disposed in the vicinity of the mounted nozzle 105. It is possible to position a mounting substrate 102 by a positioning stage 104 on which the mounting substrate 102 is disposed.

In the constitution, first, the mounting substrate 102 is positioned in a horizontal direction by use of the positioning stage 104. Moreover, the controller 108 drives the linear motor 106 to start lowering the mounted nozzle 105 in a state in which the semiconductor device 101 is adsorbed/held by the mounted nozzle 105. Subsequently, the height of the mounted nozzle 105 at this time is measured by the position sensor 107, and the position of the mounted nozzle 105 is controlled to bring soldering bumps of the semiconductor device 101 into contact with the mounting substrate 102.

When the semiconductor device 101 contacts the mounting substrate 102 in this manner, the semiconductor device 101 and mounting substrate 102 are heated by a heater table 103. When the soldering bumps of a bonded portion are molten and liquefied, the soldering bumps are pressed/crushed by a defined amount, and the semiconductor device 101 is positioned in a height

direction with respect to the mounting substrate 102. Thereafter, the mounted nozzle 105 is lifted up as if the soldering bumps were stretched.

It is to be noted that in a method of the Jpn. Pat. Appln. KOKAI Publication No. 2002-134563, an upper limit is set on a driving current value to be passed through the linear motor 106 in order to prevent the linear motor 106 from being driven at a certain thrust or more, when moving downwards the mounted nozzle 105.

Separately from the method of the Jpn. Pat. Appln. KOKAI Publication No. 2002-134563, there is a bonding method in which the semiconductor chip is bonded to the mounting substrate via an elastic member disposed between the semiconductor chip and the mounting substrate in order to secure the interval between the semiconductor chip and the mounting substrate at the height position. In the bonding method, the semiconductor chip or the mounting substrate is pressed to deform the elastic member disposed between the semiconductor chip and the mounting substrate, and a pressing force at this time is controlled. Accordingly, deformation of the elastic member is controlled to determine the interval between the semiconductor chip and the mounting substrate.

#### BRIEF SUMMARY OF THE INVENTION

According to a first mode of the present invention, there is provided a semiconductor bonding

apparatus which mounts a semiconductor chip via an elastic member disposed between the semiconductor chip and a mounting substrate, comprising:

5 a holding section which holds the semiconductor chip facing the mounting substrate;

a translatable gas bearing which is connected to the holding section and which is capable of moving the semiconductor chip in a bonding direction with respect to the mounting substrate;

10 a voice coil motor connected to the translatable gas bearing;

at least one load cell which detects a pressing force to be added to the elastic member by the holding section, when the semiconductor chip is mounted; and

15 a driving section which generates a driving signal in accordance with the pressing force detected by the load cell to drive the voice coil motor.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

25 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification,

illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

5           FIG. 1 is an appearance front view showing a constitution of a semiconductor bonding apparatus according to a first embodiment of the present invention;

          FIG. 2 is a flowchart showing a bonding procedure  
10 of the semiconductor bonding apparatus according to the first embodiment of the present invention;

          FIG. 3 is a diagram showing deformation of an elastic member at a component bonding time;

          FIG. 4 is an appearance front view showing the  
15 constitution of the semiconductor bonding apparatus according to a second embodiment of the present invention;

          FIG. 5 is a flowchart showing a bonding procedure  
20 of the semiconductor bonding apparatus according to the second embodiment of the present invention;

          FIG. 6 is a diagram showing a modification of the second embodiment;

          FIG. 7 is an appearance front view showing a  
25 constitution in which the first and second embodiments are combined; and

          FIG. 8 is an explanatory view of a prior art.

# DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described hereinafter with reference to the drawings.

## [First Embodiment]

5           A semiconductor bonding apparatus according to a first embodiment of the present invention will be described with reference to FIG. 1. FIG. 1 is a constitution diagram of the semiconductor bonding apparatus according to the first embodiment.

10           An angle plate 2 is disposed on a base 1, and a Z-stage 3 movable in a Z-direction (vertical direction in the drawing) is disposed on the angle plate 2. A guide 4 is attached to the Z-stage 3, and this guide 4 is attached to a Z-stage motor 6 via a ball screw 5.  
15           Furthermore, the Z-stage motor 6 is connected to a driver controller (hereinafter referred to as the controller) 23, and it is possible to rotate the Z-stage motor 6 at an optional speed by the controller 23. Here, examples of the Z-stage motor 6 include  
20           a pulse motor, servo motor, ultrasonic motor and the like. The Z-stage 3 may also be driven by a linear motor. In this case, the Z-stage motor 6 or the ball screw 5 is not required.

          That is, when the Z-stage motor 6 is driven by  
25           the controller 23, a rotary movement of the motor is converted to a linear movement in a bonding direction of a semiconductor chip 10 to a mounting substrate 18

via the ball screw 5, that is, in a Z-direction of  
FIG. 1. Furthermore, the guide 4 linearly moves in the  
Z-direction by the linear movement of the ball screw 5,  
and the Z-stage 3 is guided to also linearly moves in  
5 the Z-direction. Accordingly, it is possible to move  
the Z-stage 3 to an optional position at an optional  
speed. It is to be noted that the guide 4 may include  
rolling guide mechanisms such as a cross roller and  
ball guide, or sliding mechanisms such as a dovetail  
10 groove. The ball screw 5 may be another type of feed  
screw represented by a trapezoidal screw, and the screw  
is not limited to the ball screw.

A translatory gas bearing 7 is disposed on the  
Z-stage 3. For the translatory gas bearing 7, a gas  
15 pressure of a gap between the translatory gas bearing 7  
and a shaft 8 is kept to be high by the use of  
viscosity of a gas, and accordingly the shaft 8 is  
movable in a floating state from the wall surface of  
the translatory gas bearing 7. The translatory gas  
20 bearing 7 is disposed in such a manner that a movement  
axis of the shaft 8 which is a bearing object component  
is parallel to that of the Z-stage 3, and is movable  
in the Z-direction separately from the movement of the  
Z-stage 3.

25 A holding section 9 is disposed on a lower end of  
the shaft 8, and it is possible to hold the semicon-  
ductor chip 10 by the holding section 9, for example,



by vacuum adsorption. It is to be noted that a method of holding the semiconductor chip 10 may be any of methods such as grasping, electrostatic adsorption, adhesion, surface tensile force, and laser trap, and  
5 the method is not limited to vacuum adsorption.

On the other hand, an upper end of the shaft 8 is connected to an output shaft 12 of a voice coil motor (VCM) 11. The VCM 11 is electrically connected to a driving section 13. On receiving a driving signal  
10 produced by the driving section 13, the VCM 11 moves the shaft 8 in the Z-direction. The driving signal of the VCM 11 is changeable to an optional value and an optional polarity by setting by the driving section 13.

A sensor plate 14 is attached to the upper end  
15 of the output shaft 12 of the VCM 11, and further a load cell 15 is disposed under the sensor plate 14. The load cell 15 is a device which produces a voltage as an output signal in accordance with a pressing force. That is, when the VCM 11 is driven to move  
20 the shaft 8, the sensor plate 14 also moves, and the pressing force applied onto the load cell 15 changes. Accordingly, since the output signal of the load cell 15 changes, the pressing force applied by the VCM 11 can be detected. The load cell 15 is electrically  
25 connected to a display unit 16 which is capable of display the force applied to the load cell 15.

A stage 17 is disposed on the base 1, and the

stage 17 is electrically connected to the controller 23. The stage 17 is movable in each of a horizontal direction (XY direction in the drawing), a rotation direction around a Z-axis, and an inclination direction ( $\alpha\beta$ -direction in the drawing), and it is accordingly possible to position the mounting substrate 18. The stage 17 is capable of holding the mounting substrate 18, for example, by the adsorption. Accordingly, the mounting substrate 18 is disposed so as to face the semiconductor chip 10. A predetermined number of deformable elastic members 22 are arranged in predetermined positions on the semiconductor chip 10 in order to set an interval (hereinafter referred to as the substrate interval) between the semiconductor chip 10 and the mounting substrate 18 to a value desired by an operator. It is to be noted that the elastic members 22 may also be disposed on a mounting substrate 18 side beforehand, or the elastic members 22 may also be supplied after holding the semiconductor chip 10 or the mounting substrate 18.

Moreover, a middle part of the stage 17 includes a hollow structure, and a condensing lens 19 is disposed in a lower part of the stage 17 in such a manner that the mounting substrate 18 can be irradiated with light on a lower side. The condensing lens 19 is connected to an optical fiber guide 20. Another end of the optical fiber guide 20 is connected to a UV light

source 21. The UV light source 21 is a light source for hardening an adhesive material of an ultraviolet hardening type. Therefore, the mounting substrate 18 is preferably formed of materials high in ultraviolet transmissivity, such as quartz glass.

Next, a procedure at a component bonding time in the first embodiment will be described with reference to FIG. 2. The semiconductor chip 10 is adsorbed/held onto the holding section 9. Next, the mounting substrate 18 is disposed and adsorbed/held onto the stage 17. In this state, an operation of the present semiconductor bonding apparatus is started.

The controller 23 of the semiconductor bonding apparatus first moves the stage 17 to adjust the horizontal direction, rotation direction, and inclined direction of the mounting substrate 18 in such a manner that the mounting substrate 18 is brought into a predetermined position with respect to the semiconductor chip 10 (step S1). It is to be noted that in this positioning, for example, the stage 17 may be moved so as to match a marker disposed on the stage 17 with that on the holding section 9. The stage 17 does not have to be necessarily an automatic stage, and may also be a manually operated stage.

After the adjustment in this step S1, the operator operates the driving section 13, applies a driving signal to the VCM 11, and produces a thrust in the VCM

11 (step S2). This thrust is transmitted to the load cell 15 via the sensor plate 14. The display unit 16 displays the pressing force detected by the load cell 15 (step S3). It is to be noted that the pressing  
5 force actually displayed at this time includes the thrust generated by the VCM 11, and is additionally influenced by weights of constituting components connected to the sensor plate 14 such as the holding section 9, semiconductor chip 10, and VCM 11. While  
10 checking the pressing force displayed on the display unit 16, the operator adjusts the value of a current signal of the driving section 13 and selects polarity of the current signal to set the pressing force to a desired value. The driving section 13 receives this  
15 setting and adjusts the thrust of the VCM 11 to adjust the pressing force (step S4). Thereafter, the thrust of the VCM 11 is not changed. It is to be noted that the adjustment of the pressing force in the step S4 is manually performed by the operator. Additionally, the  
20 set value of the pressing force may also be input beforehand, and the driving section 13 may accordingly adjust the pressing force. It is to be noted that the set value indicates a pressing force by which the elastic members 22 are deformed by predetermined  
25 amounts. It is assumed that the pressing force is obtained beforehand by experiment or calculation.

After the adjustment of the pressing force, in

response to the manual operation by the operator, the controller 23 drives the Z-stage motor 6 to move down the Z-stage 3 toward the mounting substrate 18 (step S5). When the Z-stage 3 moves down, the semiconductor  
5 chip 10 contacts the elastic members 22. When the Z-stage 3 is further moved downwards in this state, the sensor plate 14 is detached from the load cell 15, and the pressing force applied to the load cell 15 is applied to the elastic members 22. Here, the  
10 translatory gas bearing 7 includes a mechanism which keeps the gas pressure of the gap between the translatory gas bearing 7 and the shaft 8 to be high by the use of the viscosity of the gas, so that the shaft 8 is moved in a floated state from the wall surface of  
15 the translatory gas bearing 7. Therefore, a sliding resistance generated between the translatory gas bearing 7 and the shaft 8, and a fluctuation of the resistance are remarkably small at an ignorable degree. Therefore, the pressing force which has been applied  
20 to the load cell 15 is exactly applied to the elastic members 22 in any position regardless of the position of the Z-stage 3, in other words, a relative position between the translatory gas bearing 7 and the shaft 8. At this time, the elastic members 22 are crushed and  
25 deformed by the predetermined amounts by the pressing force applied from the semiconductor chip 10 as shown in FIG. 3.

At this time, the driving section 13 judges whether or not the sensor plate 14 is detached from the load cell 15, that is, whether or not the pressing force detected by the load cell 15 is zero (step S6),  
5 and the lowering Z-stage 3 is stopped at a time when the pressing force detected by the load cell 15 turns to zero (step S7). Moreover, the Z-stage 3 may also be manually stopped while checking the value displayed on the display unit 16. Furthermore, the lowered position  
10 of the Z-stage 3 in which the elastic members 22 are deformed by the predetermined amounts may also be obtained beforehand by the experiment or the like, so that the Z-stage 3 is stopped in accordance with the lowered position.

15 After stopping the Z-stage 3, the semiconductor chip 10 is bonded to the mounting substrate 18 (step S8). That is, an adhesive 24 of the ultraviolet hardening type is charged between the semiconductor chip 10 and the mounting substrate 18 by a dispenser  
20 (not shown) in a state in which the elastic members 22 is deformed. Moreover, an ultraviolet ray is produced by the UV light source 21, and guided into the stage 17 via the optical fiber guide 20. The ultraviolet ray is bound in a predetermined spot diameter by the  
25 condensing lens 19 disposed on the tip of the optical fiber guide 20 to irradiate the underside of the mounting substrate 18. Since the ultraviolet ray is

capable of passing through the mounting substrate 18,  
the adhesive 24 of an ultraviolet ray hardening type  
hardens by the ultraviolet ray, and the semiconductor  
chip 10 is bonded to the mounting substrate 18 at a  
5 desired substrate interval. It is to be noted that the  
semiconductor chip 10 or the mounting substrate 18  
may also be coated with the adhesive 24 beforehand.  
The condensing lens 19 does not have to be necessarily  
disposed in accordance with a required work distance or  
10 irradiation intensity.

As described above, in the first embodiment, while  
checking the pressing force actually generated by the  
load cell 15, the driving signal of the VCM 11 can be  
set. Therefore, it is possible to exactly set the  
15 pressing force. It is therefore possible to exactly  
deform the elastic members 22. As a result, it is  
possible to exactly set the substrate interval between  
the semiconductor chip 10 and the mounting substrate 18  
to a desired value.

20 It is to be noted that a bonding member which  
bonds the semiconductor chip 10 to the mounting  
substrate 18 is not limited to the ultraviolet ray  
hardening adhesive 24, and a thermosetting adhesive may  
also be used. Alternatively, metal bumps such as  
25 soldering bumps and gold bumps may also be disposed.  
In this case, it is necessary to dispose a heater  
capable of heating at least one of the semiconductor

chip 10 and the mounting substrate 18 at a required temperature on the holding section 9 or the stage 17 beforehand. When the thermosetting adhesive or the like is used in this manner, it is not necessary to  
5 select the material of the mounting substrate 18 in consideration of ultraviolet ray transmissivity, and the condensing lens 19, optical fiber guide 20, or UV light source 21 is not required.

[Second Embodiment]

10 A second embodiment of the present invention will be described with reference to FIG. 4. The second embodiment is different from the first embodiment in the arrangement of the load cell. A constitution similar to that of FIG. 1 is denoted with the same  
15 reference numerals, description thereof is omitted, and only a part different from that of FIG. 1 will be described hereinafter.

That is, in the second embodiment, the load cell  
15 is disposed on the upper end of the shaft 8 which is the bearing object component of the translatory gas  
20 bearing 7, and further the shaft 8 is connected to the output shaft 12 of the VCM 11 via springs 31. The number of springs 31 is not especially limited, but a total tensile force of the springs 31 has to be  
25 larger than a total weight of all components attached to the shaft 8 including the load cell 15.

Moreover, a stopper 32 is disposed on the upper



end of the output shaft 12 in order to prevent the  
output shaft 12 from dropping from the VCM 11. The VCM  
11 is electrically connected to the driving section 13,  
and the driving section 13 is electrically connected  
5 to the controller 23. That is, the controller 23 is  
capable of controlling the driving section 13 to  
optionally control the thrust of the VCM 11. The  
controller 23 is also connected to the display unit 16,  
and is capable of controlling the driving section 13  
10 while referring to an output of the load cell 15.

Here, in FIG. 4, the load cell 15 is held by the  
shaft 8 and output shaft 12, and further undergoes a  
compression stress by the springs 31. Therefore, even  
when the pressing force is not applied to the elastic  
15 members 22, an output is constantly generated from the  
load cell 15 in accordance with the compression stress.

Next, a procedure at the component bonding time  
according to the second embodiment will be described  
with reference to FIG. 5. The semiconductor chip 10 is  
20 adsorbed/held onto the holding section 9. Next, the  
mounting substrate 18 is disposed and adsorbed/held  
onto the stage 17. The operation of the present  
semiconductor bonding apparatus is started in this  
state.

25 The controller 23 of the semiconductor bonding  
apparatus first moves the stage 17 to adjust the  
horizontal direction, rotation direction, and inclined

direction of the mounting substrate 18 in such a manner that the mounting substrate 18 is brought into the predetermined position with respect to the semiconductor chip 10 (step S11). Here, as described above,  
5 the output is generated from the load cell 15 in accordance with the compression stress from the springs 31. The controller 23 makes a correction in such a manner that the pressing force displayed on the display unit 16 turns to zero in a state in which there are  
10 compression stresses from the springs 31 (step S12).

Next, the controller 23 controls the driving section 13 to drive the VCM 11, and lifts up the output shaft 12 in an upward direction of FIG. 4 (step S13). It is to be noted that the thrust to be generated in  
15 the VCM 11 has a size equal to that of a thrust generated in the Z-stage motor 6 in the step S14. Thereafter, the Z-stage motor 6 is driven, and the Z-stage 3 is lowered toward the mounting substrate 18 (step S14). Moreover, while monitoring the output of  
20 the load cell 15 by the output from the display unit 16, the controller 23 judges whether or not the output from the load cell 15 increases by a predetermined amount (step S15). When it is judged that the output from the load cell 15 increases by the predetermined  
25 amount, the lowering of the Z-stage 3 is stopped (step S16).

Here, when the Z-stage 3 moves downwards, and the

elastic members 22 contact the mounting substrate 18,  
the mounting substrate 18 undergoes an impact load from  
the elastic members 22. However, since the output  
shaft 12 is lifted upwards by the thrust of the VCM 11,  
5 the impact load during the contact of the elastic  
members 22 with the mounting substrate 18 can be  
minimized.

After the elastic members 22 are brought into  
contact with the mounting substrate 18, the Z-stage 3  
10 is further moved downwards, the stopper 32 is detached  
from the VCM 11, and the pressing force by the weight  
of the VCM 11 is applied as a part of the pressing  
force onto the elastic members 22 via the load cell 15.  
When the increase of the pressing force is detected,  
15 the controller 23 controls the driving section 13 to  
stop lowering the Z-stage 3. It is to be noted that  
the pressing force at this time is also displayed on  
the display unit 16.

Next, after stopping the Z-stage 3, the controller  
20 23 moves the Z-stage 3 upwards or downwards so as to  
obtain the desired pressing force based on the signal  
detected by the load cell 15 (step S17). A control  
system at this time may be either open-loop control or  
closed-loop control. It is to be noted that the VCM 11  
25 may also be driven instead of the Z-stage 3. Here, the  
pressing force is adjusted after once stopping the  
Z-stage 3, but the force may also be adjusted without

stopping the Z-stage 3.

After adjusting the desired pressing force in the step S17, the semiconductor chip 10 is bonded to the mounting substrate 18 in the same manner as in the first embodiment (step S18).

In the second embodiment, unlike the first embodiment, the pressing force during the pressing of the elastic members 22 is actually detected by the load cell 15, and further the thrust of the VCM 11 can be controlled based on the output from the load cell 15. Therefore, it is possible to set the pressing force more exactly. Therefore, it is possible to more exactly deform the elastic members 22, and it is also possible to more exactly set the substrate interval between the semiconductor chip 10 and the mounting substrate 18.

It is to be noted that the shaft 8 and the output shaft 12 may also be guided in a thrust direction by a shaft, bush and the like. The lifting-up of the output shaft 12 in the step S13 is not necessarily required, and may be performed if necessary. For example, this can be omitted, when the pressing force is small.

Next, a modification of the second embodiment will be described with reference to FIG. 6. It is to be noted that here only the part different from the second embodiment will be described. In the constitution of the semiconductor bonding apparatus in this

modification, at least two spring posts 43 are disposed in the thrust direction on a flange section 44 of the shaft 8. A hole having a diameter larger than an outer diameter of the spring post 43 is made in a position  
5 for disposing the spring post 43 in a flange section 45 of the output shaft 12, and the output shaft 12 is supported by the spring posts 43 so as to be movable in the thrust direction without any load. Furthermore, compression springs 41 are disposed on the spring posts  
10 43 so as to contact the flange section 45 of the output shaft 12. Collars 42 which are movable in the thrust direction on the spring posts 43 as axes and which can be fixed/held by the spring posts 43 are disposed on the other sides of the compression springs 41. In this  
15 structure, for example, the tip of the spring post 43 is threaded, and the collar 42 may be a nut for this thread. It is to be noted that the other constitution is similar to the second embodiment.

In this constitution, first the thrust position of  
20 the collar 42 is changed to adjust the force generated by the compression spring 41. At this time, the forces generated by the compression springs 41 are adjusted in consideration of the weights of the shaft 8 and the members connected to the shaft so as to bring the load  
25 cell 15 into press-contact with the output shaft 12. Next, the thrust position of each collar 42 is determined in such a manner that the forces generated

by a plurality of compression springs 41 are prevented from deviating.

In this modification, unlike the apparatus described in the second embodiment, the generated forces of the compression springs 41 can be easily and  
5 finely adjusted. Therefore, it is possible to more exactly adjust a force for pressing the load cell 15 disposed on the shaft 8 onto the flange section 44 with good balance, and it is possible to more exactly  
10 measure the thrust generated by the VCM 11 by the load cell 15.

It is to be noted that the first embodiment may be combined with the second embodiment as shown in FIG. 7.

Additional advantages and modifications will  
15 readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various  
modifications may be made without departing from the  
20 spirit or scope of the general invention concept as defined by the appended claims and their equivalents.